ENVIRONMENTAL RACE TO THE BOTTOM: MIXED AGENT-BASED MODEL

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ABSTRACT

Whether environmental policy is best determined by the federal government or whether it is best set by the states is far from settled. On the one hand, federal policy creates uniformity and eliminates potentially wasteful competition or spillovers between states. On the other hand, states can adapt environmental policies to reflect their own circumstances. However, states might also use this flexibility to pursue goals other than protecting the environment and goals that might even be environmentally harmful. This is the so-called race to the bottom. The purpose of this work is to develop an agent-based modeling approach that can describe state-level policy-setting behavior. This model forms a policy testing platform in which alternative schemes can be examined to limit the race-to-the-bottom process. At a minimum, this model illustrates that states might adopt bifurcated strategies, which may explain the lack of empirical support for the phenomenon, and that these strategies might develop from stochastic events rather than measurable state differences.

Keywords: Race to the bottom, agent-based, environmental policy

INTRODUCTION

Decentralization of the U.S. environmental policy remains a quite controversial issue of public policy design. While there are many presumed behaviors of states as they pursue economic growth and environmental policies, the empirical evidence is quite mixed. Proponents of strong federal authority argue that if a state is given authority to set its own environmental standards, the state will set lower standards to attract economic activity. This interstate competitive effect is known as the "race to the bottom." On the other hand, their opponents are convinced that decentralization has its advantages. States may use their flexibility to either set policies that are even stricter than federal standards or to adopt alternative methods for achieving the same environmental outcomes that the federal standards would achieve but at a lower social cost by taking advantage of local circumstances.

The number of works quantitatively evaluating the process of decentralization, and consequently the existence or absence of the race to the bottom, is limited in most cases, because systematic, reliable, and timely available empirical data from the states are rarely available. In situations like that, agent-based modeling can be a powerful tool for the study. Agent-based models provide the possibility to flexibly change and control the variables of interest: the biophysical world where agents operate, agents' attributes, and rules of cooperation, punishment, learning, etc. This flexibility and adaptability make it possible to study "what if" questions. For

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example, what if agent preferences or given rules of cooperation change? How, then, may this affect the outcomes, efficiency, and effectiveness of the environmental policy? That broad control in the computer experiment is usually restricted, if not impossible, for most empirical studies because the “what if” question seems to have limited applicability to and consistency with regard to empirical data.

In the present work, we attempt to define the main features of an agent-based modeling approach that may provide us with an insight into state-level environmental policy setting and help us understand how economic development within the states and competition between the states may affect their environmental regulations and vice versa. To define the main attributes of the agents — the rules of their behavior and interaction — we consider a simple model of the state’s economy producing one good by using one input and generating hazardous waste. In this approach, we assume the stringency of the environmental policy is defined by the environmental tax, which is endogenous with respect to agents. Finally, we discuss some difficulties in establishing the rules of agents’ behavior and possible situations that may lead to complex dynamics.

PRIOR LITERATURE

Federalism and federal-state relations within environmental policy are extensively discussed by many scholars in the field (e.g., Sussman et al. 2002; Scheberle 2004; Braden and Proost 1997). Decentralization of federal power with respect to environmental policy may follow different processes. So-called “delegated” programs offer to the states a partial preemption of primacy in setting environmental quality. Standards established by a state must be at least as strict as the federal standards. Under the Clean Air Act, states are delegated with the right to design old source performance standards while new source performance remains under federal jurisdiction. Under the Clean Water Act, states may also choose to accept primary control over both new and old sources (and some states do) in setting water quality standards. Under the Resource Conservation and Recovery Act (RCRA), states are given broad control over the tax structure and permissible practices for the generation, treatment, disposal, and transportation of hazardous wastes. The federal government does not provide complete funding to the state running its own programs. Sussman et al. (2002) notes the distinct differences in states in choosing primacy as their motivation. These beneficial factors include the following: (1) the state earns flexibility in setting the environmental standards and may provide a higher level of environmental protection; (2) states may set priorities for their programs to take into consideration local circumstances; (3) states can establish their own in-state programs when there is no similar federal program; (4) states can consider their own administrative capacity in setting goals; (5) states may take into account local political and technological concerns; (6) states may establish the respective agency of a different type and size that answers the state’s needs. This also benefits federal government, providing a possibility to save some funds for other social programs together with achieving a positive environmental outcome.

But the added flexibility brings the concern that states may set lower environmental standards or postpone the implementation of federal standards (see, for example, Engel 1997 and Revesz 2001). Scholars, advocating stronger federal authority, argue that interstate competition in industrial development causes states to relax their environmental standards in favor of their business communities (e.g., Duerksen 1983). This effect leads to a situation where each state may export the cost of its more lenient clean air standards: more pollution in the air to other states. At the same time, "the economic growth attracted by lower standards occurs exclusively within each state's boarders" Potoski (2001). The literature on these issues follows purely theoretical and purely empirical tracks.

Oates and Schwab (1988, 1996) developed a set of theoretical models. In their models, interstate competition results in states establishing environmental standards at the socially effective level. At the other extreme, Engel (1997) characterizes the problem as a one-shot prisoner's dilemma game. She identifies the crucial difference between the two models. Under her model, the *two* noncooperating states always produce the race-to-the-bottom outcome, while Oates and Schwab's model assumes a number of competitors that is large enough so that the market equilibrium remains unchanged when one of the states attracts capital by lowering its environmental standards. The large number of competitors (states) use the competitive equilibrium assumption that no state is large enough to distort the market. Engel suggests that even with more than two states, some might collude to relax standards and have a nontrivial impact on attracting capital, creating the race-to-the-bottom outcome.

Relatively few papers take an agent-based modeling approach for anything remotely close to this subject. Teitelbaum (1998) uses agents to model the ways in which firms adapt to changed regulatory environments. Teitelbaum showed that the government controls pollution more effectively when firms are given time to prepare for the onset of pollution regulations rather than being surprised by them and that the effects of pollution controls can vary widely across firm types. Batroszchuk and Nakamori (2002) used agent-based modeling together with empirical data to testify on the existence of the environmental Kuznets curve for carbon dioxide emissions for four European countries.

There are a number of purely empirical studies that attempt to test the race-to-the-bottom hypothesis. Potoski (2001) builds a regression model with the dependent variable being the number of criteria pollutants for which a state exceeds national ambient air quality standards (NAAQSs). Only the variables characterizing community-based action appeared to be significant. Another paper (Bond et al. 2004) gives similar results, which show that the level of environmental ambient standards for both air and water are defined by the level of democracy and environmental preferences of agents (citizens, groups, communities) acting in the state. The economic variables, like polluting industry strength, appeared to be insignificant, providing no evidence for the race to the bottom. List and Gering (2000) found no evidence for the race to the bottom in environmental quality from their study of abatement expenditures of the states. Dinan et al. (1999) had the same result for drinking water. In summary, most empirical works do not provide convincing evidence that the environmental race to the bottom exists. However, it is not clear if any of these studies appropriately control for simultaneity and/or selectivity. Policies may be strictest where the pollution problem is the most severe.

The race to the bottom is closely related to the "pollution haven" hypothesis. Several recent studies found empirical evidence for the existence of a pollution haven effect: pollutants are exported to states with less stringent environmental regulations, and firms in polluting industries are more likely to locate to those states. But even more studies do not support this result. Kahn and Yoshino (2004) analyzed pollution intensity and distribution of the bilateral manufacturing trade. The panel data analysis of whether richer or poorer nations specialize in exporting dirty goods done for 1980–1997 in 128 countries for 34 manufacturing industries supports the pollution haven hypothesis. Contrasting with this, one of the more influential studies (Ederington et al. 2004) examined whether trade liberalization affects environmental quality in the United States and found no such relation. Smarzynska and Wei (2004) studied investments flows to 25 developing countries. The study was done on an individual firm level, and it also provided no support to the pollution haven hypothesis. The paper by Copeland and Taylor (2004) includes an extensive literature review in which the authors expressed their vision of the problem and theoretical analysis of the topic. In another paper, Taylor (2004) develops a theoretical model of the pollution haven hypothesis by dividing the hypothesis into a series of logical steps, linking assumptions on exogenous country characteristics to predictions on trade flows and pollution levels. As was mentioned above, the application of the game theory to the pollution problem has some serious technical and conceptual limitations: in reality, many parties participate in setting environmental standards; the setting of standards is a dynamic process that includes different kinds of dynamic interactions between players in both vertical and horizontal planes, etc. (see, for example, Brander 1985).

In summary, one may conclude that the race to the bottom is one of the possible behavioral responses of the state to the decentralization of the environmental policy. There is still no solid empirical proof that states do or do not reveal this type of behavior in setting the environmental standards. Most empirical works conclude that the data being used do not provide evidence of the race to the bottom. Together, they suggest that agent-based models have the potential to contribute a lot to this subject.

ELEMENTS OF THE AGENT-BASED MODEL

In approaching this issue, we assume that the model will consist of n agents representing states (or jurisdictions). We assume that each agent (for example, agent i), produces two aggregated commodities: a clean good x_{ci} and a dirty good x_{di}. Production of the dirty good also implies the production of waste x_{pi}. We also assume that there is only one mobile input to production: labor L_i. The production functions are increasing, concave, and homogeneous of the first order. The use of only one input has a number of modeling advantages for describing economic behavior. First of all, we don't need to set a set of strong assumptions about the mobility of the capital, the comparative advantage of each agent, capital or labor abundance, etc. (see Oats and Schwab 1988) putting limitations on the number of agents. Second, it offers us the ability to describe behavior within and among states without the difficulty of establishing internal and external markets so that we can avoid the necessity of solving for a general equilibrium at each time period. Third, as mentioned above, there is some empirical evidence that the effect (price) of labor on waste generation has a higher magnitude then environmental regulations. With regard to the last point, we assume, consequently, that there is no incentive for an agent to transfer its capital to another agent, which is reasonable unless we don't model the location decision process of the firms.

The environmental regulations are set endogenously by the individual agents (state governments) each time period. We assume that the stringency of the regulations is defined by an environmental tax rate τ_i for the disposal of wastes within the state's boundaries. These tax rates may be set differently by each state. The states can also allocate resources L_{ai} for the abatement of hazardous waste generation. The abatement function $x_{pi} = g(L_{ai}, x_{di})$ increases in x_{di} and declines in L_{ai}. The higher the amount of the dirty good x_{di} that is produced, the more waste x_{pi} is generated. The practicality of this assumption is driven by our desire to include only one kind of agent in the model. If we included other agents (firms, for example), they would decide on the levels of effort to apply to abatement, possibly on the basis of command-and-control-type regulations. The view of firm decision making in this model is that it is very simplistic and nonstrategic. Once their production activities are included in the states' aggregate production, firms simply do what the states want them to do. As a last dimension to state-level behavior, they decide what to do with the wastes that are generated. They may dispose of them within state boundaries, making them subject to the waste disposal tax. Or, alternatively, they may decide to ship them to another state for disposal. This makes them subject to the other state's disposal tax plus any shipping and handling fees. The diagram describing the production-waste generation process for two agents is shown in Figure 1.

Ceteris paribus, there are two main pieces of information that affect the agent's decision to ship waste out of the state that are made by the agent: the total shipment cost and difference in taxes. From a rational point of view, one may consider the net benefit, which is equal to the difference between revenue due to taxes colleted for the waste kept by the agent and the total cost of the shipment to the other agent. These two pieces of information can be summarized by the "vision" φ_{ki} that agent k has of agent *k*. A higher fraction of wastes are sent to states with high vision than with low vision. The waste from state *k* sent to state *i* is described by $x_{pki} = \varphi_{ki} x_{pi}$.

To consider a simple situation, suppose that there are no transportation or handling charges. Under these circumstances, states send waste to whichever state has the lowest tax rate. This is the presumed behavior behind the race to the bottom. Under these circumstances, and with only two agents, if the environmental tax set by the agent-sender *j* is higher than the tax of the agent-acceptor *I,* then $0 < \varphi_{ji} \leq 1$, and zero otherwise. This situation may well be formally described by using the Heaviside function $\varphi_{ji} = \vartheta(\tau_j - \tau_i)$. In general, the cost of shipment is

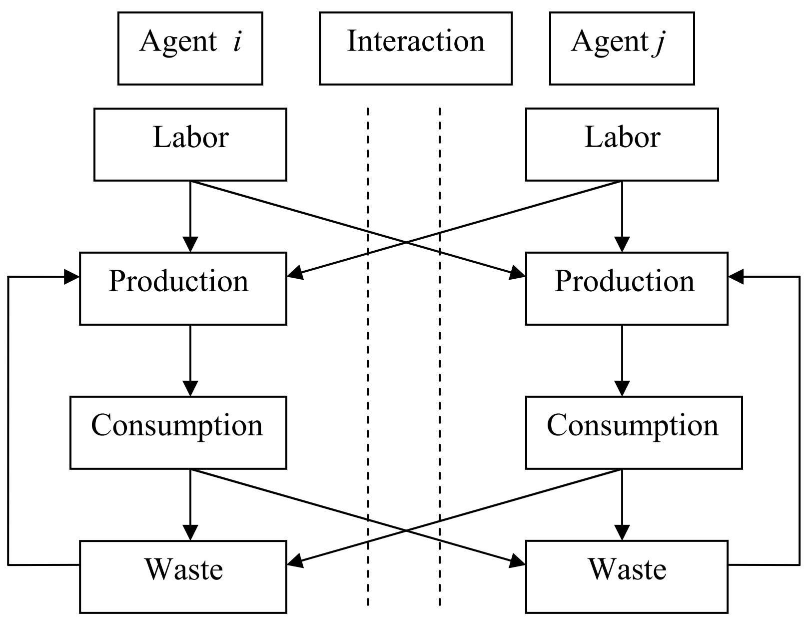

FIGURE 1 Diagram of the production-waste generation process

proportional to the spatial distance d_{ji} between the agents, and we use a logistic allocation function to reflect these two components in the "vision" function:

$$\varphi_{ji} = \vartheta(\tau_j - \tau_i)\frac{\exp(\tau_j - \tau_i - \gamma d_{ji})}{\sum_{all\,k}\exp(\tau_j - \tau_k - \gamma d_{jk})}, \tag{1}$$

where γ is a marginal transportation cost set to be equal across all agents.

At each period, we assume that each agent maximizes a discounted sum of its utility function *U(X*, *–D)* over the time horizon. The utility function consists of two parts. The first part relates to the total income for the agent: $x_{ck} + p_d x_{dk} + \tau_k x_{pkr} - (\tau_i + \gamma) x_{pko}$, where x_{ck} has a unit price); τ_k and τ_i are the waste taxes set by the agent *k* and agent *i*, respectively; x_{pkr} is the amount of waste received from all other agents; and x_{pko} is the amount of waste shipped to agent *i.* We assume that agent *k* will likely ship to only the agent considering the tradeoff between the lower tax and minimal transportation cost. The second part of *U(X*, *–D)* represents the damage function $D = D(x_{pk} + x_{pkr} - x_{pko})$; x_{pk} is the amount of waste generated by the agent *k*. It is reasonable that the damage function is an increasing function of the total amount of wastes that are stored in the state, though it is likely that it will increase at a decreasing rate. What is ultimately important in this model is the way that the net amount of wastes disposed of in the state enter into the calculation about total utility.

There some potential problems that may appear to lead the behavior of the agent to the race to the bottom. Assume that environmental tax τ reduces the amount of waste by $(1 - \tau^*)$ as follows (see, for example, Lempert et al. 2003):

$$x_{p,t+1} = \delta(1 - \tau^*) x_{pt} \quad . \tag{2}$$

This transformation describes a regime with a unique trajectory while τ^* is a constant. In reality, some U.S. states have no taxes at all, while others use step-functions (CCH 2002). For the sake of simplicity, we assume that the tax rate may be expressed in the following form:

$$\tau_t^* = \begin{cases} \tau_{1t} x_{pt} & if \quad x_{pt} \le x_{p0t} \\ \tau_{2t} & if \quad x_{pt} > x_{p0t} \end{cases} . \tag{3}$$

Note that τ_1 and τ_2 measured in different units are a tax ceiling. Also, in reality, τ_t does not change much over time. In the case of the United States, the change of the disposal tax schedule happens once in 5 to 10 years. Hence, while modeling, we can treat it as a constant during up to 10 time cycles. On the other hand, an environmental policy decision-maker ought to have (and we assign him with) the possibility to intervene in the policy at any time cycle. By substituting Equation 3 into Equation 2, one gets the nonlinear recurrent expression:

$$x_{p,t+1} = \delta(1 - \tau_{1t} x_{pt}) x_{pt} \tag{4}$$

for the amount of waste, which itself may produce unexpected behavior.

The main issue in modeling the race to the bottom is how to classify the phenomena. The difficulty here is that the modeler predefines rules according to which agents behave, and then they simply reflect that behavior. The stringency of the environmental regulations is an endogenous parameter with respect to the agent, and each agent itself should define and implement the rule of how to adjust it. But even this simple-enough system may reveal complex, dynamic behavior. Under a certain combination of parameters, one may expect additional complexity because of the interaction between the agents. For example, the use of Equation 3 for pollution calculations may get the system switched to the chaotic regime, producing bifurcations. The same regulations applied to different agents may produce different effects. Recall that most empirical works do not find convincing evidence that the effect takes place because the respective regression coefficients were found to be not significant. The reason may be that the measured value lies in such a zone.

DISCUSSION

The race to the bottom is one of the possible responses of the state to the decentralization of environmental policy. There is no still solid empirical proof that states do or do not reveal this type of behavior in setting environmental standards. Most empirical works conclude that the data being used do not provide evidence of the race to the bottom. On the other hand, it is a presumed part of environmental policy making that this behavior exists. The models that give rise to this kind of behavior (e.g., prisoner's-dilemma-type models) do not reflect the reasonable dynamic context of the problem.

Recall that the main difficulty here is that the decision to relax the environmental regulations should be endogenous for each agent. The decision to relax policy is to be made by an agent itself. It should be clear that if the modeler establishes the respective rule for the agent, the agent will switch to the race to the bottom, following exactly that rule. In this situation, the inverse approach may be reasonable: initially the system of the agents starts its development with agents interacting with each other. Then we randomly choose an agent and relax its environmental standard to study how the dynamics of both the whole system and the agent change. Another approach proposed above is to allow the agent to maximize its utility adaptively to choose the optimal behavior with respect to the environmental tax.

Finally, we discussed some difficulties that are likely to be encountered in the modeling approach used for the race-to-the-bottom phenomenon and possible nonlinear dynamic behavior that complicates the process.

REFERENCES

Bartoszczuk, T., and Y. Nakamori, 2002, "Environmental Kuznets Curve for Some Countries Regression and Agent-based Approach," in C.A. Brebbia and J.F. Martin-Duque, eds., *Air Pollution X* , WIT Press, pp. 93–102.

Bond, C.A., and Y. Hossein Farzin, 2004, *Freedom from Pollution? The State, the People, and the Environmental Kuznets Curve;* available at http://repositories.cdlib.org/are/arewp.

Braden, J., and S. Proost, 1997, *The Economic Theory of Environmental Policy in a Federal System*, Cheltenham, UK: Edward Elgar.

Brander, J., 1985, "Economic Policy Formation in a Federal State: A Game Theoretic Approach," in "Royal Commission on the Economic Union and Development Prospects for Canada," Vol. 63, in R. Simeon, ed., *Intergovernmental Relations,* Toronto, Ontario, Canada: University of Toronto Press, pp. 33–66.

CCH, 2003, *State Tax Guide*, Commerce Clearing House, Inc.

Copeland, B., and S. Taylor, 2004, "Trade, Growth, and the Environment," *Journal of Economic Literature* 42(13):7–71.

Dinan, T.M., M.L. Cropper, and P.R. Portney, 1999, "Environmental Federalism: Welfare Losses from Uniform National Drinking Water Standards," in A. Panagariya et al., eds., *Environmental and Public Economics: Essays in Honor of Wallace E. Oates,* Cheltenham, U.K.: Edward Elgar, pp. 13–31.

Duerksen, C., 1983, *Environmental Regulation of Industrial Plant Sitting: How to Make it Work Better,* Washington, DC: Conservation Foundation.

Ederington J., A. Levinson, and J. Minier, 2004, "Trade Liberalization and Pollution Havens," *Advances in Economic Analysis & Policy* 4(2), Article 6.

Engel, K., 1997, "State Environmental Standard-setting: Is There Race and Is It to the Bottom?" *Hastings Law Journal* 48(2):271–398.

Kahn, M.E., and Y. Yoshino, 2004, "Testing for Polution Havens inside and outside of Regional Trading Blocks," *Advances in Economic Analysis & Policy* 4(2), Article 4.

Lempert, R., S.W. Popper, and S.C. Bankes, 2003, *Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis,* Santa Monica, CA: RAND.

List, J.A., and S. Gerking, 2000, "Regulatory Federalism and US Environmental Policies," *Journal of Regional Science* 40(3):453–471.

Oates, W.E., and R.M. Schwab, 1988, "Economic Competition among Jurisdictions: Efficiency Enhancing or Distortion Inducing?" *Journal of Public Economics* 35(3):333–354.

Oates, W.E., and R.M. Schwab, 1996, "The Theory of Regulatory Federalism: The Case of Environmental Management," in W.E. Oates, ed., *The Economics of Environmental Regulation*, Cheltenham, UK: Edward Elgar, pp. 319–331.

Potoski, M., 2001, "Clean Air Federalism: Do States Race to the Bottom?" *Public Administration Review* 61(3):335–342.

Revesz, R.L., 2001, "Federalism and Regulation: Some Generalizations," in D. Esty and D. Geradin, eds., *Regulatory Competition and Economic Integration: Comparative Prospective,* Oxford: Oxford University Press, pp. 3–29.

Scheberle, D., 2004, *Federalism and Environmental Policy: Trust and the Politics of Policy Implementation, Second Edition*, Washington, DC: Georgetown University Press.

Smarzynska B.J., and S.J. Wei, 2004, "Pollution Havens and Foreign Direct Investment: Dirty Secret or Popular Myth?" *Advances in Economic Analysis & Policy* 3(2), Article 8.

Susssman, G., B. Daynes, and J. West, 2002, *American Politics and the Environment,* New York, NY: Longman.

Taylor, S., 2004, "Unbundling the Pollution Haven Hypothesis," *Advances in Economic Analysis & Policy* 4(2), Article 8.

Teitelbaum, D., 1998, "Technology Change and Pollution Control: An Adaptive Agent-based Analysis," Ph.D. dissertation, Department of Engineering and Public Policy, Carnegie Mellon University: Pittsburgh, PA.